PROTECTA
Electronics Co. Ltd

EuroProt
complex protection
DFTK-EP

factory configuration for

frequency-dependent load shedding

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CONTENTS

1 Field of application

The **EuroProt** complex protection is basically a modular device. The modules are assembled and configured according to the application. This manual describes only one of the numerous possibilities: the **DFTK-EP** factory configuration. The general description of the **EuroProt** devices is the document „**EuroProt complex protection, hardware and software description and user's manual**", (further „*EuroProt manual*").

The large electric power systems keep the frequency near to the rated frequency value. In case of large disturbances however some parts of the system can remain alone with power surplus or lack of sufficient power. In these parts of the system the frequency starts to deviate from the rated value. This deviation can increase the disturbances. To avoid total shutdown, the system is protected with under-frequency relays, the task of which is to disconnect some pre-determined consumers from the system, and keep the power balance. So the total shutdown of the system can be prevented.

The over-frequency version of this protection function can be applied e.g. as reserve protection of the generators against over-speed.

In normal operation the frequency of the electric power system changes within a narrow range only (about ±30 mHz), as a consequence of faults or disturbances however during system swings the deviation can be out of this range with some tenth of Herz as well.

When setting the stages of the under-frequency protection, these system swings must be taken into consideration as well. Because of these swings, some frequency stages could start and drop off periodically, if the frequency is changing around the setting value. This can be avoided by setting the hysteresis (drop-off ratio) parameter. At the lowest frequency of the swings the stage can start operation, at the upper frequency value it cannot drop off caused by this hysteresis. When setting the frequency parameter, it should be below the smallest possible operating frequency of the system by twice of the hysteresis value.

When setting the starting and drop-off time delay, care must be taken: the drop-off time should be shorter than the starting time delay, to allow dropping off, if the frequency swings on a somewhat higher level.

The **DFTK-EP** type frequency-dependent load shedding factory configuration of the EuroProt devices can be applied to perform frequency related protection tasks.

Any of the four frequency stages can be programmed independently of each other as over- or under-frequency functions. The output commands of the stages can be directed to pre-defined consumer groups as well.

The integrated „frequency independent" load shedding function can distribute four remote commands to consumer groups as well.

The integrated SCADA functions extend the device to a complex bay unit for medium voltage networks.

1.1 Main characteristics of the complex device

- The protection functions of the **DFTK-EP** factory configuration are as follows:
  - Four independent frequency stages;
  - The parameter setting of the frequency stages (over- or under-frequency protection, the setting value, the hysteresis and the time delay) is independent of each other;
  - The stages can be disabled, independently of each other by parameter setting or by digital input signals;
  - The frequency stages operate only if the measured voltages are above a certain level, as it is set by a parameter;
  - In the described factory configuration the trip commands of the frequency stages can be directed to up to 27 output relay contacts (the number of contacts can be extended to 43);
  - The device transmits four (local or remote) trip commands via software matrix: these are the „frequency independent load shedding" commands; the source of these commands can be digital inputs or commands from the supervisory and control system, via serial communication
  - The four remote trip command can be directed to these 27 (max 43) output relay contacts as well.

- The supervisory and control functions integrated into the device:
  - The supervisory and control functions are performed by a dedicated micro-controller of the CPU module of the device;
  - The supervisory and control functions integrated into the device are as follows:
    - Transmission of status signals,
    - Transmission of measured analogue values,
    - Receipt and processing of remote commands.

- The device is programmed for continuous and periodical self-check functions.
- An event log is programmed to store up to 50 events, the event sequence log can contain up to 300 digital events with 1 ms time resolution time stamps.
- The real-time clock integrated into the device is operating by a battery supported RAM. This clock can be synchronised by an external PC or by the supervisory and control system, and additionally a Protecta-mad World Time Synchroniser (GPS-OP) is available as well.

- The integrated disturbance recorder of the CPU module can store up to 11 records of analogue and digital time functions. The total registering time can be about 10 s.

1.2 Main hardware characteristics

The **DFTK-EP** factory configuration of the complex digital EuroProt system is a fully numerical device, based on microprocessors. The integrated functions and the versions are defined within the hardware limitations by the software.

The design of the device and the man-machine interfaces are described in the „*EuroProt manual*".

The operation of the device can be performed using the integrated man-machine interface (2x16 character LCD and 6 push-buttons on the front panel), but the operation is easier and quicker using an external PC, running the operating software „**Protect for Windows**", developed by Protecta Co. Ltd. Instructions for both operating possibilities are included in the „*EuroProt manual"*.

The external communication can be performed either the serial RS232 interface of the front panel, designed to withstand 2 kV test voltage, or via integrated fibre optic connectors on the CPU module rear side. The application of these interfaces is described in the „*EuroProt manual"*.

2 Operation of the frequency related protection functions

2.1 Frequency measurement

The three line-to-line input voltages are summed with weighting factors (1-$\sqrt{3}$-2), and the hardware generates a square wave. The time between the rising edges of this square wave is measured by time counting. The frequency can be calculated with mHz accuracy. The algorithm signals to the further processing routines if the detected frequency is within the acceptable limits (45-55 Hz).

2.1.1 Realisation of the frequency stages

The **DFTK** factory configuration realises four frequency stages. The operation and the setting of the stages are independent of each other.

2.1.1.1 The analogue inputs of the function

The function receives three voltages, usually three line-to-line voltages of a voltage transformer set:

U1 U2 U3

There are four digital inputs assigned to the function, the active states of which disables the individual frequency stages:

Stage 1. disable Stage 2. disable Stage 3. disable Stage 4. disable

2.1.1.2 Parameter setting

The function needs setting of the following parameters:

LCD text	Min	Max	Step	Explanation
f1<> /100 Hz	4500	5500	1	Frequency setting of the first frequency stage, the value expressed in Hz can be calculated by dividing the parameter value with 100
f1 hysteresis= /100 Hz	2	200	1	The hysteresis (drop off ratio) of the first stage, both for over- and under-frequency applications
f1 over/0 under/1	0	1	1	In case of setting „0” of this parameter the first stage operates as over-frequency function, when setting „1” it operates as an under-frequency stage
t(f1<>) = ms	0	50000	50	Time delay of the first frequency stage
f1<> disabled /+=yes/	0	1	1	Disabling of the first frequency stage
f2<> /100 Hz	4500	5500	1	Frequency setting of the second frequency stage, the value expressed in Hz can be calculated by dividing the parameter value with 100
f1 hysteresis= /100 Hz	2	200	1	The hysteresis (drop off ratio) of the second stage, both for over- and under-frequency applications
f2 over/0 under/1	0	1	1	In case of setting „0” of this parameter the second stage operates as over-frequency function, when setting „1” it operates as an under-frequency stage
t(f2<>) = ms	0	50000	50	Time delay of the second frequency stage
f2<> disabled /+=yes/	0	1	1	Disabling of the second frequency stage

f3<> /100 Hz	4500	5500	1	Frequency setting of the third frequency stage, the value expressed in Hz can be calculated by dividing the parameter value with 100
f3 hysteresis= /100 Hz	2	200	1	The hysteresis (drop off ratio) of the third stage, both for over- and under-frequency applications
f3 over/0 under/1	0	1	1	In case of setting „0” of this parameter the third stage operates as over-frequency function, when setting „1” it operates as an under-frequency stage
t(f3<>) = ms	0	50000	50	Time delay of the third frequency stage
f3<> disabled /+=yes/	0	1	1	Disabling of the third frequency stage
f4<> /100 Hz	4500	5500	1	Frequency setting of the fourth frequency stage, the value expressed in Hz can be calculated by dividing the parameter value with 100
f4 hysteresis= /100 Hz	2	200	1	The hysteresis (drop off ratio) of the fourth stage, both for over- and under-frequency applications
f4 over/0 under/1	0	1	1	In case of setting „0” of this parameter the fourth stage operates as over-frequency function, when setting „1” it operates as an under-frequency stage
t(f4<>) = ms	0	50000	50	Time delay of the fourth frequency stage
f4<> disabled /+=yes/	0	1	1	Disabling of the fourth frequency stage
U1> V	40	90	5	The frequency stages are operable only if there is at least one analogue input, the measured voltage of which is above the setting value
t(f1234) drop-off ms	150	1500	150	Common drop-off time setting for the four stages

These parameter settings are displayed in the „Parameters” window of the „Protect for Windows” program as:

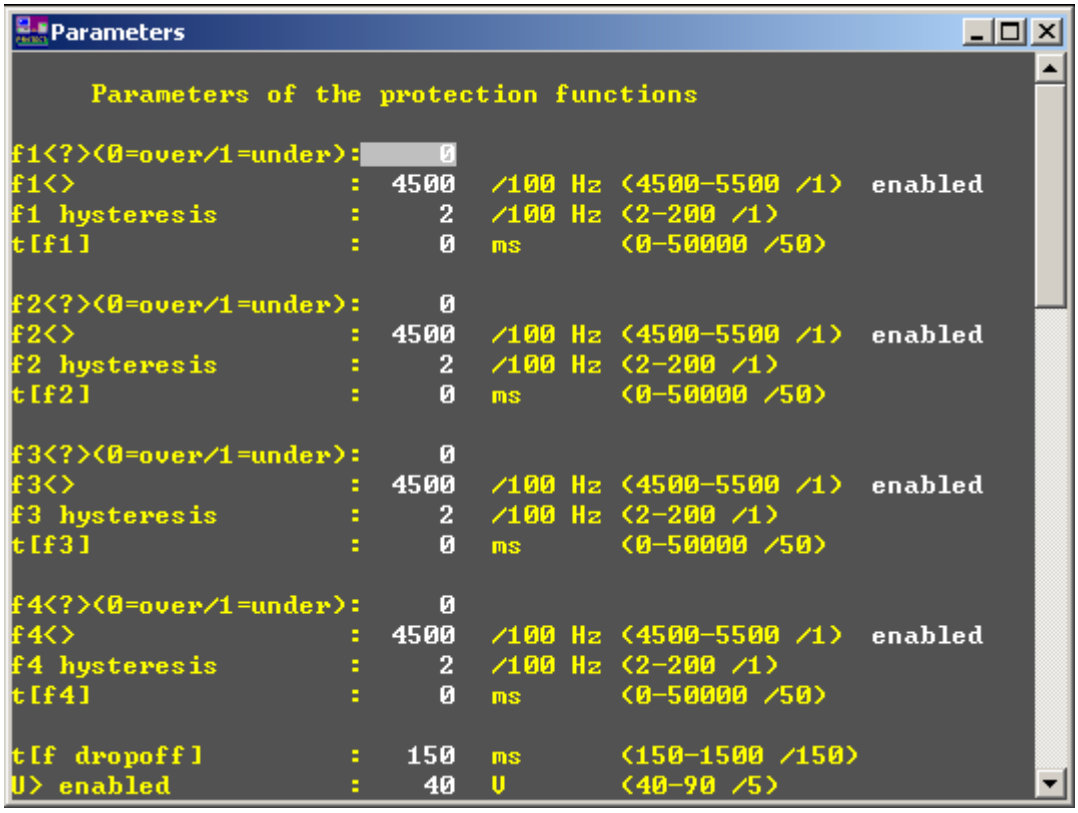

Fig.2-1. Parameter setting

In this window when clicking on enabled text, it changes to disabled, and the referred stage gets inactive.

2.1.1.3 Outputs of the function

In the factory configuration there are dedicated relay contacts to output the trip commands of the frequency stages, and there are signal contacts to indicate the disabled state of the stages as well.

```
f1<>t1 trip
f2<>t2 trip
f3<>t3 trip
f4<>t4 trip
1.stage disabled
2.stage disabled
3.stage disabled
4.stage disabled
```

Additionally the functions generate status signals of the operation of the functions (matrix-rows), which can be marshalled to the outputs (matrix-columns), and/or they are input variables for the „PROTLOG" equations as well.

Matrix rows on the LCD of the device, related to the frequency function:

Matrix-row	**Explanation**
DFTK st.1.trip	Trip command of the first frequency stage
DFTK st.2.trip	Trip command of the second frequency stage
DFTK st.3.trip	Trip command of the third frequency stage
DFTK st.4.trip	Trip command of the fourth frequency stage

These signals can be directed to the outputs, using the software matrix programming.

The matrix columns:

Matrix column	**Explanation**
Bay 1 …	Command directed to the circuit breaker of bay No. 1 …..
…Bay 27	… Command directed to the circuit breaker of bay No. 27

The Figure below shows a screen-shot of the „Parameters" window of the „Protect for Windows" software. Here, as an example, the trip command of the first frequency stage is directed to the circuit breakers of bays 1, 2, 5, 8 and 23, the marshalling of the other three stages can be seen on the Figure similarly.

(The remote trip signals on the Figure are explained later.)

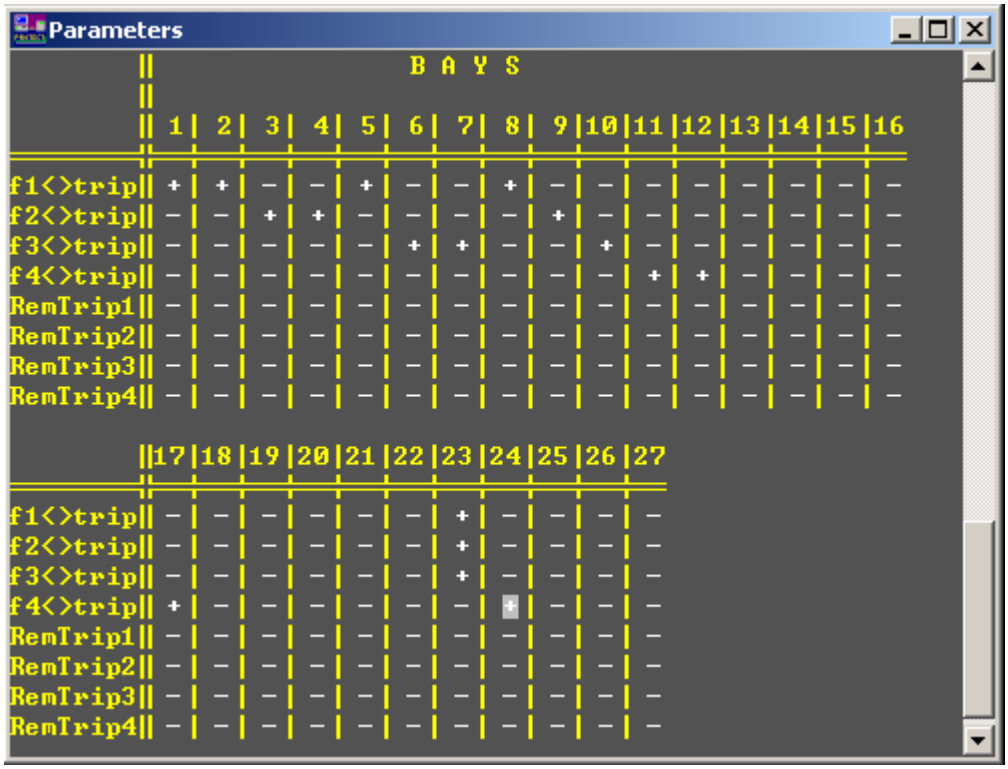

Fig. 2-2. Matrix programming (example)

2.1.1.4 Inputs for the PROTLOG equations

The inputs for the PROTLOG equations, related to the frequency stages are listed in the Table below.

PROTLOG input	Explanation
f1 <> Start f2 <> Start f3 <> Start f4 <> Start	Started state of the individual frequency stages
f1 <> [t] f2 <> [t] f3 <> [t] f4 <> [t]	Timeout of the individual frequency stages, they generate trip commands
U1ena> U2ena> U3ena>	The indicated voltage is above the level setting, they enable operation of the frequency stages

2.1.1.5 The displayed information

In the „Test” menu of the LCD the following measured analogue signals and status information can be read:

LCD	Explanation
U1/Un [%.] = U2/Un [%.] = U3/Un [%.] =	The RMS value of the indicated voltages, expressed as pro mill of the voltage transformer's rated voltages
f[mHz] =	The measure frequency in mHz units
DFTK status:	(binary words)
Stage1Disabled Stage2Disabled Stage3Disabled Stage4Disabled	Disabled state of the indicated frequency stages (right to left)
Stage1Trip Stage2Trip Stage3Trip Stage4Trip	Trip command of the indicated frequency stages (right to left)

The information is displayed in the „On-line” window of the „Protect for Windows” software as shown in Figure below (information related to other functions are screened out):

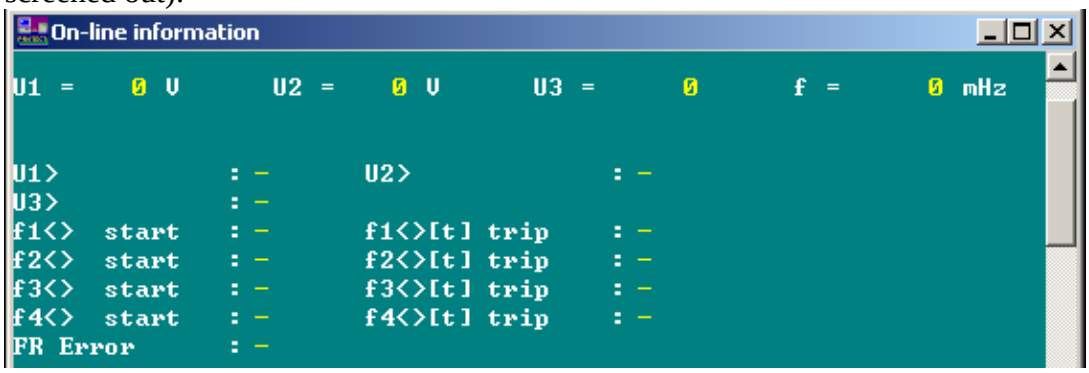

Fig. 2-3. „On-line” information

Explanation on the digital information displayed in the „On-line Window”:

Information	**Explanation**
U1> U2> U3>	The referred voltage is above the setting level
f1<> start f2<> start f3<> start f4<> start	Starting of the referred frequency stage
f1<>[t] trip f2<>[t] trip f3<>[t] trip f4<>[t] trip	Trip command of the referred frequency stage
FR Error	Error state of the frequency measurement, there are no voltages to evaluate

2.1.1.6 Counters

The following counters are assigned to the frequency stages (on the LCD screen):

```
DFTK 1st st.trip count:
DFTK 2nd st.trip count:
DFTK 3rd st.trip count:
DFTK 4th st.trip count:
```

The „On-line” window of the „Protect for Windows” software shows this information as follows:

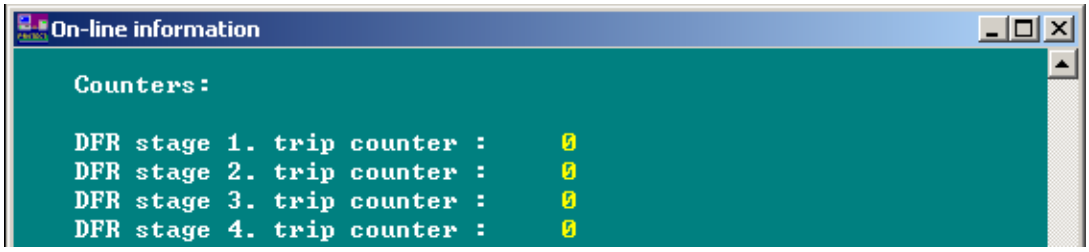

Fig. 2-4.Counters in the „On-line” window

2.1.1.7 LED indication

There are seven LEDs on the front panel, to indicate the operation of the functions in the device. The following LED-s are assigned to the over/under-frequency stages:

LED ID No.	LED text	Explanation
2	f1 TRIP	Trip command of the first frequency stage
3	f2 TRIP	Trip command of the second frequency stage
4	f3 TRIP	Trip command of the third frequency stage
5	f4 TRIP	Trip command of the fourth frequency stage
6	Disabled	All frequency stages are disabled
7	Volt Error	No available voltages

2.1.1.8 Signals recorded in the disturbance recorder

The function transmits the following signals to the integrated disturbance recorder:

Analogue signals:

Signal	Explanation
U1 [%] U2 [%] U3 [%]	The values of the sampled voltages, as percent of the voltage transformer rated voltage
fr [mHz]	The measured frequency in mHz

Digital signals:

Signal	Explanation
f1<> f2> f3> f4>	Started state of the referred stage
U1> U2> U3>	The referred voltage is above the level

2.2 The „frequency-independent" load shedding function

The **DFTK-EP** factory configuration can receive remote commands basically from three sources. First of all there are four hardware input connectors, the signals (commands) of which are distributed among the available outputs, which are assigned to circuit breakers in the bays (the number of which is in the discussed configuration 27). Additionally the commands can be received via serial communication as well. The third possibility is the „Controls" window of the „Protect for Windows" program, running on the connected PC.

2.2.1 Remote command execution

If any of the hardware inputs receive a command, a dedicated timer is started, the running time of which is defined by parameter setting. The duration of the output command is the duration of the input signal or the running time of the timer, whichever is longer.

The commands can be marshalled with software matrix to the outputs.

2.2.1.1 Inputs of the function

The digital inputs of the function are:

Digital input	Explanation
External trip 1 External trip 2 External trip 3 External trip 4	The four dedicated inputs

2.2.1.2 Parameter setting

This function needs setting of the following parameters (common for all four inputs):

LCD	Min	Max	Step	Explanation
Remote trip imp. ms	200	60000	10	The minimal duration of the output impulse
Remote tr. disabl /+=yes/				If the setting is „+", then the remote trip command is disabled

The settings related to this function on the „Parameters" screen of the „Protect for Windows" program (parameters related to other functions are screened out):

Fig. 2-5. Parameter setting /2

2.2.1.3 The software matrix

The matrix rows related to the function are:

Matrix row	Explanation
RemTrip 1	Command received on External trip 1 digital input
RemTrip 2	Command received on External trip 2 digital input
RemTrip 3	Command received on External trip 3 digital input
RemTrip 4	Command received on External trip 4 digital input

These signals can be marshalled to the available relay contacts.

The matrix columns:

Matrix column	Explanation
Bay 1 …	Command directed to the circuit breaker of bay No. 1 …..
…Bay 27	… Command directed to the circuit breaker of bay No. 27

Fig. 2.2 above shows the programming possibilities related to the „frequency-independent load shedding" function as well.

The method of matrix programming is described in the „*EuroProt manual*".

2.3 The PROTLOG equations

The available digital status signals can be used to program logic equations, the results of which can start the integrated disturbance recorder function.

2.3.1.1 Input signals of the PROTLOG equations

The available inputs signals are listed in the table below:

Input signal	Explanation
f1 <> Start	Started state of the first frequency stage
f2 <> Start	Started state of the second frequency stage
f3 <> Start	Started state of the third frequency stage
f4 <> Start	Started state of the fourth frequency stage
U1 ena>	The voltage measured as U1 is sufficient to enable frequency stages
U2 ena>	The voltage measured as U2 is sufficient to enable frequency stages
U3 ena>	The voltage measured as U3 is sufficient to enable frequency stages
f1 <> [t]	Trip command of the first frequency stage
f2 <> [t]	Trip command of the second frequency stage
f2 <> [t]	Trip command of the third frequency stage
f2 <> [t]	Trip command of the fourth frequency stage
SW1 Acknowl	The SW1 push-button on the front panel of the device is depressed
SW2	The SW1 push-button on the front panel of the device is depressed

The input signals marked with „*” leading character mean latched signals.

2.3.1.2 Outputs of the PROTLOG equations

Output	Explanation
DistRec. LevelTrig	Triggering signal of the integrated disturbance recorder function: The recording time duration is the same as the active state of the triggering signal, but the size is limited by the page size of the memory. If this signal is active, no new triggering is possible, even if the recording stopped because of the page limitation.
DistRec. EdgeTrig	Triggering signal of the integrated disturbance recorder function: the recording starts at the rising edge of the signal. The „pre-fault” time and the recording duration is factory setting.

2.3.1.3 Programming the PROTLOG equations

The PROTLOG equations can be programmed with a connected PC, using the graphic programming method of the „Protect for Windows" operating program.

The method of programming is described in the „*EuroProt manual*".

2.4 Local command processing

The „Controls" window of the „Protect for Windows" operating software can be used to acknowledge the latched LEDs or generate commands to the defined groups of circuit breakers. This window is displayed on the PC screen as it is shown below:

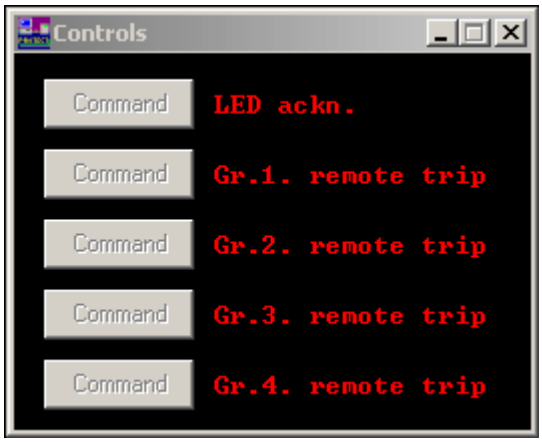

Fig. 2-6. Local commands from the „Protect for Windows" operating software

The "LED ackn." command resets the latched LED-s on the front panel of the device.

The remote trip commands start individual timers. During the running time of the timers, the dedicated inputs of the software matrix „`RemTrip1…4`" get logic state „1". According to the matrix programming, these states can be directed to the relay output contacts of the device (in this configuration 27 relays, max. 43 relays). The groups include the bays according to the programming of the frequency-independent load shedding function. The duration of the trip command is equal to the duration of the active state of the timers.

2.5 The integrated disturbance recorder function

The CPU module of the EuroProt device includes an integrated disturbance recorder function as well This disturbance recorder stores the sampled analogue and status signals. This function does not have own man-machine interface, it can communicate with the external PC connected via fibre optic connection only. The records can be analysed on the screen of the connected PC or in the central protection engineering workstation.

The recorded functions are discussed in connection with the frequency stages (section 2.1.1.8).

The integrated disturbance recorder has factory settings, the only intervention possibility for the user is to define triggering conditions using the PROTLOG equations of the „Protect for Windows" program. (See details in the „*EuroProt manual"*).

2.6 The event recorder function

The integrated event recorder stores the status signal changes with 1 ms time resolution. The sequence of events can be displayed in the „Events" window of the „Protect for Windows" operating software. The possible digital events in the DFTK-EP factory configuration are listed in the following table:

Events	**Explanation**
DFR 1. stage trip DFR 2. stage trip DFR 3. stage trip DFR 4. stage trip	Trip command of the indicated frequency stage
Bay 1. trip Bay 2. trip ... Bay 27. trip	Trip command generated for circuit breaker of the indicated bay
DFR out of OP	The frequency stages are not operable
DFTK out of OP	The frequency dependent load shedding function is not operable
DFR st 1. disabled DFR st 2. disabled DFR st 3. disabled DFR st 4. disabled	The indicated frequency stage is disabled
Gr. 1. rem.trip Gr. 2. rem.trip Gr. 3. rem.trip Gr. 4. rem.trip	Remote trip commands for the indicated groups of bays, received via digital inputs, serial communication or generated by the „Controls" window of the „Protect for Windows" operating software.

2.7 Summary of the LED indications

There are seven LEDs on the front panel of the device to indicate the operation of the functions in the device. As a summary of the descriptions of the LED-s described in connection with the frequency-related functions, the seven LED-s indicate the following events:

LED ID No.	LED text	Explanation
1	LCD	Warning LED signal: shows that there is new information on the front panel LCD of the device, or in case of parameter changes the acknowledgement of the operator is needed
2	f1 TRIP	Trip command of the first frequency stage
3	f2 TRIP	Trip command of the second frequency stage
4	f3 TRIP	Trip command of the third frequency stage
5	f4 TRIP	Trip command of the fourth frequency stage
6	Disabled	All frequency stages are disabled
7	Volt Error	No available voltages

2.8 Displayed system messages

If the self-check function detects an error, a message text is displayed on the front panel LCD of the device. The following list shows the possible system messages:

```
EEPROM error !
Memory battery low !
Self check : A/D error !
+- 15V power suppl. failure!
No new events!
DFTK-EP 30.11.2004V/2.01
```

A message can be acknowledged by pressing the ENTER push-button, the effect of which is to delete the message. If more than one message is active, after pressing ENETER for the first message, the following one is displayed. After acknowledgement of the last active message the red LED indicating active messages disappears.

The messages are not displayed in the sequence of occurrence, but they keep the sequence of the list above.

The error signals of the self-checking function are recorded in the event log as well. In this log up to 50 events can be stored. In the digital event sequence log the events are stored with 1 ms time resolution. This log can store up to 300 events.

The acknowledgement does not mean that the event is deleted from the log. The event log can be displayed using the menu system of the LCD on the front panel of the device, and the contents of the event log and that of the event sequence log can be displayed on the PC screen or in the protection engineering workstation as well.

2.9 The self-check function

The „watch-dog" circuit supervises the correct operation of the program system. Additionally there are continuous and cyclic self-test functions programmed in the device.

The internal self-check functions include checking of:

- The integrity of the memory storing the parameter values,
- The healthy state of the voltage of the battery supported RAM, storing the events,
- The correct operation of the A/D converter as well.

In case of any detected errors the „OK" output relay resets. This signal can be delayed by setting the following parameter:

LCD text	Min	Max	Step	Explanation
t[CHK]= ms	100	10000	20	Time delay for error signalling

The setting on this time delay in the „Parameters" window:

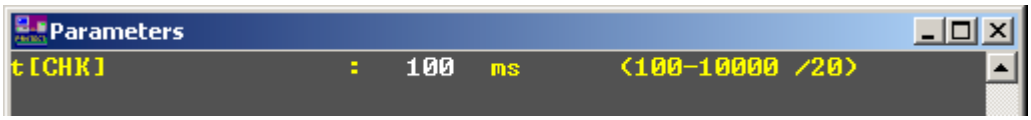

Fig. 2-7. Parameter setting /3

The status bits in the menu of the front panel LCD „DFTK error" are explained in the table below:

LCD text	Explanation
DFTK error:	Error status of the self-check function
EERPOM error	EEPROM memory error for parameter storage
Batt. error	Battery supported RAM error for event storage
AD error	Error of the A/D converter
CHK	Healthy state of the device

Error signals in the „On-line" window of the „Protect for Windows" operating program:

Fig. 2-8. Error signals

3 Arrangement of the DFTK-EP factory configuration

The design of the device is described in the „*EuroProt manual*”.

The arrangement of the modules and the assignments of the connections depend on the configuration of the device. These drawings are attached to the device.

4 Ordering information

The ordering of the device is supported by a formula, which needs filling the following information:

- Type of the device: EuroProt complex device, DFTK-EP factory configuration
- Rated power supply voltage
- VT rated secondary voltage
- Special interruption capability of the relay contacts (2 A - 4 A)
- Type of mounting: wall mounted flush-mounted
- Other options